Introduction

ANSI/TIA-222-G-2005

• A big change – the biggest since 1986
• 9 years of Work
• Published August 2005
• Addendum 1 published October 2006
• Addendum 2 published by January 2008
Revision G Philosophy – Why Change?

• New Technology
  – Engineering Theory – LRFD vs. ASD – Explicit Impact
    • Controversial – LRFD is not universally used
    • ASD has not been updated since 1989
    • A merged LRFD and ASD manual may appear in the future
  – Computing Resources – Implicit impact
    • Increase computing power allows greater calculation/programming sophistication
  – Research – Implicit Impact
    • Bracing capacity - ERI
    • Wind Tunnel Studies - PiRod
    • Greater Understanding of Wind Loads - EUROCODE

• Building Code Consolidation
  – Simplify building permit process nationally
  – Unify the application –
    • Development of the IBC
      – Consolidation of
        » SBC
        » UBC
        » BOCA
Revision G Philosophy – Why Change?

• Changes in Environmental Loads
  – New Wind Speed Measurement Techniques
    • Shift from Fastest mph to 3-Second Gust
    • Government Mandated Change
  – Development of National Ice Loads
    • ASCE-7 ’05 will make ice loads mandatory
    • Study now covers the entire United States
  – Seismic Loading
    • May govern in very special circumstances

Revision G Philosophy – Why Change?

• A desire by the Main Committee to improve buyer/user confidence
  – Eliminate the “interpretations” that may not be compatible with theory or the intent of the standard
  – Define the rules. Less reliance on “Engineering Judgment”
  – Acknowledgement that revision F did not always allow the user/buyer to make a confident competent comparison of competing designs
  – Raise the bar
  – Create an International Standard (IASS Moscow Feedback)
Loads – Different Type

2.3.2 Strength Limit State Load Combinations

Structures and foundations shall be designed so that their design strength equals or exceeds the load effects of the factored loads in each of the following limit state combinations:

1. \(1.2D + 1.0D_E + 1.6W_L\)
2. \(0.9D + 1.0D_E + 1.6W_L\)
3. \(1.2D + 1.0D_E + 1.0\ Ei + 1.0 W_L + 1.0 T_i\)
4. \(1.3D + 1.0D_E + 1.0 E\)
5. \(0.9D + 1.0D_E + 1.0 E\)

Exceptions:

1. Temperature effects need not be considered for self-supporting structures.
2. Ice and earthquake loading need not be considered for Class 1 structures.
3. No load factor shall be applied to the initial tension of guys.
4. Load combinations 2 and 5 apply to self-supporting structures only.

Notes:

1. A limit state conversion factor for ice load is applied to ice thickness in 2.6.8
2. Unfactored dead loads shall be used to determine earthquake loads, \(E_i\), in loading combinations 4 and 5.
3. For foundation designs, the weight of soil and substructure shall be considered as dead load in all loading combinations.

Developing a Wind Load

- Classify the structure by use and risk
  - Classification will adjust the return period.
  - How will the structure be used (Ham Operation vs. 911)?
  - What is the risk to life and property (Located in a urban environment vs. Rural)?

- What is the local environment?
  - Exposure to wind (surface roughness). Exposure Categories: B, C, and D.
  - Topography (flat or on top of a hill). Topographic Categories 1 through 5.
Return Periods

• Class I – 25 year return Period
  – Probability of occurrence in one year = 0.04
  – Importance Factor, I = 0.87
    • Creates a wind pressure that is
      – 13% less than Class II, (7% decrease in windspeed)
      – 24% less than Class III (13% decrease in windspeed)

• Class II – 50 year return Period
  – Probability of occurrence in one year = 0.02
  – Importance Factor, I = 1.00
    • Creates a wind pressure that is
      – 13% Greater than Class I, (7% increase in windspeed)
      – 15% less than Class III, (7% decrease in windspeed)

• Class III – 100 year return Period
  – Probability of occurrence in one year = 0.01
  – Importance Factor, I = 1.15
    • Creates a wind pressure that is
      – 13% Greater than Class II, (7% increase in windspeed)
      – 24% Greater than Class I (13% increase in windspeed)

Exposure Categories – Exposure B

• Urban and Suburban
• Wooded Areas
• Filled with Obstructions the Size of Single Family Dwellings
• Must surround the structure at least 2,630 ft or 10 times the structure height in all directions whichever is greater
Exposure Categories – Exposure C

- Open terrain with scattered obstructions having heights generally less than 30 ft [9.1 m].
- This category includes flat, open country, grasslands and shorelines in hurricane prone regions.

Exposure Categories – Exposure D

- Flat, unobstructed shorelines exposed to wind flowing over open water (excluding shorelines in hurricane prone regions) for a distance of at least 1 mile [1.61 km].
- Shorelines in Exposure D include inland waterways, lakes and non-hurricane coastal areas. Exposure D extends inland a distance of 660 ft [200 m] or ten times the height of the structure, whichever is greater.
- Smooth mud flats, salt flats and other similar terrain shall be considered as Exposure D.
Wind

- Shift from “Fastest mph” to “3-second Gust” wind speed
  - Government changed the measurement standard in the early 1990’s (ASCE 7-95)
  - Conversion Factors

### ANNEX L: WIND SPEED CONVERSIONS (Normal)

This annex provides conversion of wind speeds based on various averaging periods to the 3-second gust wind speed. Wind data based on other averaging periods are to be converted to a 3-second gust wind speed for use with the standard.

<table>
<thead>
<tr>
<th>3 sec gust (mph)</th>
<th>Fastest mph</th>
<th>10 min avg (mph)</th>
<th>Hourly mean (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>50</td>
<td>42</td>
<td>49</td>
</tr>
<tr>
<td>70</td>
<td>55</td>
<td>49</td>
<td>45</td>
</tr>
<tr>
<td>80</td>
<td>60</td>
<td>58</td>
<td>53</td>
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<tr>
<td>90</td>
<td>70</td>
<td>62</td>
<td>58</td>
</tr>
<tr>
<td>100</td>
<td>80</td>
<td>69</td>
<td>63</td>
</tr>
<tr>
<td>110</td>
<td>90</td>
<td>73</td>
<td>70</td>
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<tr>
<td>120</td>
<td>100</td>
<td>80</td>
<td>75</td>
</tr>
<tr>
<td>130</td>
<td>110</td>
<td>87</td>
<td>83</td>
</tr>
<tr>
<td>140</td>
<td>120</td>
<td>95</td>
<td>93</td>
</tr>
<tr>
<td>150</td>
<td>130</td>
<td>104</td>
<td>106</td>
</tr>
<tr>
<td>160</td>
<td>140</td>
<td>111</td>
<td>113</td>
</tr>
</tbody>
</table>

Notes:
1. For conversion to [km/h] multiply the above values by 0.447
2. Linear interpolation may be used between the values shown.
• Ice map is developed for Glaze only.
• It does not include Rime Ice
• An analytical estimate based upon computer modeling and empirical observations
• The Wind on Ice and Ice thickness listed cannot be separated. The model is based upon a wind mechanism that drives ice accumulation. Lower winds will result in a different ice thickness and vice versa.
Wind on Ice & Ice

1. The importance factors shift the ice loading return periods in the same manner as the 3-second gust wind speed.
2. It is a defined requirement.
3. 1/4" ice can be ignored.
4. Pay close attention to special wind regions indicated by the shaded areas.
5. All values represent zones. No interpolation.
6. Pay attention to the notes in the figure.

Terrain Features (Topography)

EIA Standard has adopted the 5 categories defined by ASCE
However, the calculations were simplified.

- Escarpment
- 2-D Ridge or 3-D Axisymmetrical Hill
**Terrain Features**

**Category 1:** No abrupt changes in general topography, e.g. flat or rolling terrain, no wind speed-up consideration shall be required.

Category 1 – No Impact, Terrain Features are ignored.

**Category 2:** Structures located at or near the crest of an escarpment. Wind speed-up shall be considered to occur in all directions. Structures located on the lower half of an escarpment or beyond 8 times the height of the escarpment from its crest, shall be permitted to be considered as Topographic Category 1.

Structures A & B – Category 1

Structures C & D – Category 2

Category 1 – No Impact, Terrain Features are ignored.
Terrain Features

Category 3: Structures located in the upper half of a hill. Wind speed-up shall be considered to occur in all directions. Structures located in the lower half of a hill shall be permitted to be considered as Topographic Category 1.

Structures A & B – Category 1
Structures C & D – Category 3

A hill is a rise from average terrain in all directions.

Category 1 – No Impact, Terrain Features are ignored.

Terrain Features

Category 4: Structures located in the upper half of a ridge. Wind speed-up shall be considered to occur in all directions. Structures located in the lower half of a ridge shall be permitted to be considered as Topographic Category 1.

Structures A & B – Category 1
Structures C & D – Category 4

A ridge is a rise from average terrain in two directions.

Category 1 – No Impact, Terrain Features are ignored.
Terrain Features

Category 5: Wind speed-up criteria based on a site-specific investigation.

For topographic category 5, $K_{zt}$ shall be based on recognized published literature or research findings.

Use IBC or ASCE 7-05
Topographic Features

- Escarpment
- Hill
- Ridge

Default Environmental Values

As listed in ANNEX A: PROCUREMENT AND USER GUIDELINES

- Default Structure Class: II
- Exposure Category C
- Topographic Category 1
- Assume the guy elevations are equal to the base elevation
- Default Seismic Site Class D (Stiff Soil)
Antenna Loads

- Area calculations derived utilizing a standardized approach
- Less latitude for the designer.
- Must include antenna pipes – Depends on the direction under consideration

- Design Wind Force on Appurtenances
  - The design wind force on appurtenances (either discrete or linear but excluding microwave antennas), \( F_A \), shall be determined from the equation:
  - \( F_A = q_z G_h (EPA)_A \)
  - Where \( (EPA)_A = K_a [(EPA)_N \cos^2(\theta) + (EPA)_T \sin^2(\theta)] \)
    - \( (EPA)_N = \sum (C_{aA} A_N) \)
    - \( (EPA)_T = \sum (C_{aA} A_T) \)

- Equivalent flat plate areas based on Revision C of this Standard shall be multiplied by a force coefficient, \( C_a \), equal to 2.0 except when the appurtenance is made up of round members only, a force coefficient of 1.8 may be applied.

Appurtenances

- Diagrams illustrating wind force on appurtenances with equations and symbols.

14
Appurtenances

<table>
<thead>
<tr>
<th>Member Type</th>
<th>Aspect Ratio ≤ 2.5</th>
<th>Aspect Ratio = 7</th>
<th>Aspect Ratio &gt; 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>$C_a$</td>
<td>$C_s$</td>
<td>$C_s^2$</td>
</tr>
<tr>
<td>Round</td>
<td>$C &lt; 32$ [4.4]</td>
<td>$C_s$</td>
<td>$C_s^2$</td>
</tr>
<tr>
<td></td>
<td>(Subcritical)</td>
<td>$0.70$</td>
<td>$0.80$</td>
</tr>
<tr>
<td></td>
<td>$32 &lt; C ≤ 64$</td>
<td>$3.76(C)^{2.50}$</td>
<td>$3.37(C)^{2.50}$</td>
</tr>
<tr>
<td></td>
<td>[4.4 ≤ C ≤ 0.7]</td>
<td>[1.43(C)^{2.50}]</td>
<td>[1.47(C)^{2.50}]</td>
</tr>
<tr>
<td></td>
<td>(Transitional)</td>
<td>$3.76(C)^{2.50}$</td>
<td>$3.37(C)^{2.50}$</td>
</tr>
<tr>
<td></td>
<td>$C &gt; 64$ [8.7]</td>
<td>$0.60$</td>
<td>$0.60$</td>
</tr>
<tr>
<td></td>
<td>(Supercritical)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where:

$C = (f \text{ Kts} \times 0.5 \times V(D))$ for $D$ in ft. $V$ in mph [m/s].

$V$ is the basic wind speed for the loading condition under investigation.

$D$ is the outside diameter of the appurtenance.

Aspect ratio is the overall length/width ratio in the plane normal to the wind direction.

(Appartenance is independent of the spacing between support points of a linear appurtenance, and the section length considered to have uniform wind load).

Wind Speed Domains

- Subcritical – Reynolds Numbers, $Re < 2.78 \times 10^5$
- Transitional - $2.78 \times 10^5 \leq Re \leq 5.56 \times 10^5$
- Supercritical – Reynolds Numbers, $Re > 5.56 \times 10^5$
Windspeed Domain – Subcritical to Transitional to Supercritical

**Exposure B**

<table>
<thead>
<tr>
<th>Critical Heights</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>110</th>
<th>120</th>
<th>130</th>
<th>140</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Windspeed Domain – Subcritical to Transitional to Supercritical

**Exposure C**

<table>
<thead>
<tr>
<th>Critical Heights</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>110</th>
<th>120</th>
<th>130</th>
<th>140</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Windspeed Domain – Subcritical to Transitional to Supercritical

**Exposure D**

[Diagram with data table]

### Appurtenances

**Defined Default Cellular Antenna Areas for bids**

<table>
<thead>
<tr>
<th>Carrier Type</th>
<th>No ice</th>
<th>Ice $t \leq 0.50''$ [l $\leq 13$ mm]</th>
<th>Ice $0.50'' &lt; t \leq 1.50''$ [13 &lt; t $\leq 38$ mm]</th>
<th>Transmission Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light (9 antennas max)</td>
<td>55 [6.5]</td>
<td>0.75 [3.3]</td>
<td>75 [7.9]</td>
<td>1.00 [3.3]</td>
</tr>
</tbody>
</table>
Line Loads

- LINE LOADS CAN NO LONGER BE CONSIDERED AS PART OF THE SECTION AREA!
- It is an appurtenance. No longer a distinction between discrete and linear
- The designer will utilize the same force coefficients, $C_a$, factors that are applied to antennas, and other “discrete” appurtenances.

Line Loads

Sheltering:
- Based upon voids ratio (1 - $\varepsilon$)
- Only applicable to sub-critical flow.
- Sheltering effects allowed when the line loads are entirely on the inside of the structure or is outside the cross section of the and entirely within the face zone.
Line Clusters

\[(EPA)_A = K_a[(EPA)_A \cos^2(\theta) + (EPA)_T \sin^2(\theta)]\]

Can be treated as individual lines.

Must treat as rectangular line clusters utilizing \((EPA)_A\) Approach.

Lines and Monopoles

- Section 2.6.9.1.2
  
  Note: In the absence of a detailed transmission line layout and installation bend radii of the lines, the minimum diameter of a pole structure shall not be less than the diameter which results in 45% utilization of the cross-section for the placement of internal transmission lines.

USE INTERPRETATION A!

Remember: “In the absence of a detailed transmission line layout and installation bend radii of the lines”
Mount Loads

- Mount loads will be defined and calculation procedures are established.
- Divided into broad approaches
  - Mounting Frames
  - Symmetrical Frame/Truss Platform
  - Low Profile Platform
  - Symmetrical Circular Ring Platform
  - \((EPA)_A = K_a[(EPA)_N \cos^2(\theta) + (EPA)_T \sin^2(\theta)]\)

Mounting Frames

K_a = 0.8 can be applied to antennas and antenna mounting pipes mounted on the Symmetric Frame/Truss Platform. Subcritical Flow Only!

A reduction of the structure forces is not allowed

Figure 2-6: Multiple Mounting Frames
$K_a = 0.8$ can be applied to antennas and antenna mounting pipes mounted on the Symmetric Frame/Truss Platform. Subcritical Flow Only!

A reduction of the structure forces is not allowed.

Figure 2-7: Symmetrical Frame/Truss Platforms

$K_a = 0.8$ can be applied to antennas and antenna mounting pipes mounted on the Symmetric Frame/Truss Platform. Subcritical Flow Only!

A reduction of the structure forces is not allowed.

Figure 2-8: Low Profile Platforms
$K_a = 0.8$ can be applied to antennas and antenna mounting pipes mounted on the Symmetric Frame/Truss Platform. Subcritical Flow Only!

A reduction of the structure forces is not allowed.

![Figure 2-9: Circular Ring Platforms](image)

**Mounts – Universal Issues**

- Notes for all mounting frame/platform types:
  - $K_a$ shall equal 1.0 for antennas and antenna mounting pipes under transitional or supercritical flow conditions.
  - Grating and other horizontal working surfaces need not be included in the effective projected area.
Shielding

\[ K_a = 1.0 \] if the shielding principals listed are to be applied.

Seismic Loads

- New Section – A response to changes in building codes and a greater understanding of how seismic loads occur.
Seismic – Earthquake Loads

- Based upon
  - Site Classification – Ignored for Site Class I
  - Structure irregularities
    - Not required if the Short Period ($S_s$) is less than 1.00.
    - Not required for structure there is a structural irregularity and when the equivalent seismic base shear is less the 50% of the 50 year return period wind loading.

<table>
<thead>
<tr>
<th>Description of Structure</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structures that due to height, use or location represent a low hazard to human life and damage to property in the event of failure and/or wind load is less than 1.00. For structures of lower magnitude, the base shear is likely to be less than the wind loading.</td>
<td>I</td>
</tr>
<tr>
<td>Structures that due to height, use or location represent a substantial threat to human life and damage to property in the event of failure and/or wind load is greater than 1.00.</td>
<td>II</td>
</tr>
<tr>
<td>Structures that due to height, use or location represent a high hazard to human life and damage to property in the event of failure and/or wind load is greater than 1.00.</td>
<td>III</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structure Class</th>
<th>Wind Load Without Ice</th>
<th>Wind Load With Ice</th>
<th>Ice Thickness</th>
<th>Earthquake</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1.00</td>
<td>1.00</td>
<td>N/A</td>
<td>1.00</td>
</tr>
<tr>
<td>II</td>
<td>1.00</td>
<td>1.00</td>
<td>N/A</td>
<td>1.00</td>
</tr>
<tr>
<td>III</td>
<td>1.15</td>
<td>1.25</td>
<td>N/A</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Note: Ice and earthquake loads do not apply to Class I structures.
## Structure Irregularities

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsional Irregularity</td>
<td>Center of mass of a section including appurtenances is offset from the vertical alignment of the structure by more than 30% of the smallest plan dimension of the section.</td>
</tr>
<tr>
<td>Stiffness Irregularity</td>
<td>Average bending stiffness of a section ( \left( \frac{I_S}{L_S} \right) ) varies by more than 50% from an adjacent section.</td>
</tr>
<tr>
<td>Mass Irregularity</td>
<td>Mass per unit length ( \left( \frac{M_S}{L_S} \right) ) of a section including appurtenances varies by more than 200% from an adjacent section.</td>
</tr>
</tbody>
</table>

Where: \( I_S \) = average moment of inertia of a section  
\( M_S \) = total mass of a section  
\( L_S \) = length of a section  

### Notes:  
1. A section of a structure shall be considered as the portion between leg connections for latticed structures and the distance between splices in tubular pole structures, not to exceed 50 ft [15 m] for any structure.  
2. The mass and stiffness of guys for guyed masts shall be excluded when determining irregularities.  
3. Torque arms, star mounts, etc. shall not be considered as a stiffness irregularity.  
4. Mounting frames, antenna mounts, platforms, etc. shall not be considered as a stiffness irregularity.

## Seismic Analysis Procedure Methods

<table>
<thead>
<tr>
<th>Analysis Procedure Method Description 1</th>
<th>Height Limitations on Analysis Procedure Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent Lateral Force, Method 1 in accordance with 2.7.7</td>
<td>No mass or stiffness irregularities per Table 2-9</td>
</tr>
<tr>
<td>Equivalent Modal Analysis, Method 2 in accordance with 2.7.8</td>
<td>With mass or stiffness irregularities per Table 2-9</td>
</tr>
<tr>
<td>Modal Analysis, Method 3 in accordance with 2.7.9</td>
<td></td>
</tr>
<tr>
<td>Time-History Analysis, Method 4 in accordance with 2.7.10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pole Type</th>
<th>Self-Supporting</th>
<th>Guyed Masts 2</th>
<th>Self-Supporting</th>
<th>Guyed Masts 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>No Limit</td>
<td>No Limit</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Limit</td>
<td>50 ft [15 m]</td>
<td>100 ft [30 m]</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>1500 ft [457 m]</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

### Notes:  
1. Vertical seismic forces may be ignored for Methods 1, 2 & 3.  
2. Method 4 shall be used when the horizontal distance from the base of the structure to any guy anchor point exceeds 1000 ft [305 m].
Seismic – Earthquake Loads

When required, earthquake loads shall be evaluated in accordance with the seismic analysis procedures specified in 2.7.4.

1. An importance factor I shall be determined from Table 2-3 based on the structure classification listed in Table 2-1.
2. Determine an appropriate seismic analysis procedure method for the structure from Table 2-10.
3. Determine the maximum considered earthquake spectral response acceleration (expressed as a ratio to the acceleration due to gravity) at short periods ($S_h$) and at 1 second ($S_1$) from 2.7.5.
4. Determine the Site Class based on the soil properties at the site in accordance with Table 2-11.
5. Modification factors $F_a$ and $F_v$ based on the Site Class, shall be determined from Tables 2-12 and 2-13 respectively.
6. The design spectral response acceleration at short periods (SDS) and at 1 second (SD1) shall be determined in accordance with 2.7.6.

---

Seismic – Site Class

The soil type will define the **Shake of the Quake**

<table>
<thead>
<tr>
<th>Site Class</th>
<th>Description of Upper 100 ft [30.5 m] of Soil for the Site Location</th>
<th>Standard Penetration Resistance, N</th>
<th>Undrained Shear Strength, $S_u$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Hard rock with 10 ft [3 m] or less of soil overburden.</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>B</td>
<td>Competent rock with moderate fracturing and weathering with 10 ft [3 m] or less of soil overburden.</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>C</td>
<td>Very dense soil, soft rock or highly fractured and weathered rock.</td>
<td>&gt; 50</td>
<td>&gt; 2 ksf [100 kPa]</td>
</tr>
<tr>
<td>D</td>
<td>Stiff soil.</td>
<td>15 to 50</td>
<td>1.0 to 2.0 ksf [50 to 100 kPa]</td>
</tr>
<tr>
<td>E</td>
<td>Weak soil (excluding site class F).</td>
<td>&lt; 15</td>
<td>&lt; 1.0 ksf [50 kPa]</td>
</tr>
<tr>
<td>F</td>
<td>Soils vulnerable to potential failure or collapse under seismic loading.</td>
<td>Soil profiles over 10 ft [3 m] thick with $P_i \geq 20$, moisture content $\leq 40%$, $S_u &lt; 0.5$ ksf [25 kPa]</td>
<td>Soil profiles containing any of the following: peat and/or highly organic clays over 10 ft [3 m] thick, very high plasticity clays ($P_i &gt; 75$) over 25 ft [7.6 m] thick, soft/medium clays over 120 ft [36.6 m] thick, liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils.</td>
</tr>
</tbody>
</table>

Analogy: Rock (Site Class A) vs. Jell-O (Site Class E-F)
Earthquake Detailing
Still driven by building codes and engineering practices. Not a part of the standard.
Considered covered as a product of the
“Standard of Practice of the Engineering Profession”

Serviceability
- The standard lists a minimum recommendation.
- 60 mph 3-second gust windspeed recommended.
- Serviceability should be derived based upon performance and reliability of the system. Consider Issues such as
  - Redundancy -
  - Economic loss – Cost of the structure is inversely proportional to increasing the serviceability requirements of the structure. (Does not include RF Issues)
  - Acceptable risk – Life and property (Consider impact upon society, Communications role in society.)
- Values used:
  - $1.0 \cdot D + 1.0 \cdot D_g + 1.0 \cdot W_o$ (Refer to 2.3.1)
    - $D_g$ – Dead load of guys
    - $D$ – Dead Load of the structure and appurtenances, excluding guys
    - $W_o$ – wind load without ice.
  - Importance Factor = 1.0 (Remember this is a return period modifier)
  - Exposure Category and Topography Factors should remain unchanged.
Analysis

• Specific techniques are required
  – Meant to correct issues like
    • A guyed tower Column that is too narrow
    • Guy spans that are too large
    • Underestimating loads
      – Tuning the member selection process too closely to the results of the wind analysis.
      – Inflection points reflect a mathematical concept.
      – A tall tower is subjected to wind that will move up and down the tower in approximately 180 ft long segments. The movement of gusts up and down the tower will eliminate the “inflection points.”

Analysis - General Issues

Patch Loading
Analysis Techniques – What is acceptable? Section 3.4

(a) Self-Supporting Latticed Towers

1. An elastic three-dimensional truss model made up of straight members pin connected at joints producing only axial forces in the members.

2. An elastic three-dimensional frame-truss model where continuous members (legs, K-type bracing horizontals without plan bracing) are modeled as 3-D beam elements producing both moments and axial forces in the members while the remaining members which are subjected primarily to axial loads may be modeled as 3-D truss elements producing only axial forces in the members.

(b) Self Supporting Pole Structures:

1. An elastic three-dimensional beam-column model producing moments, shears and axial forces in the pole structure.

2. Unless the analysis model considers second order effects within each element, the minimum number of beam elements shall be equal to five per pole section and the maximum beam element length shall not exceed 6 ft.

3. Note: Due to modeling complexity (e.g. meshing, element interconnection, ...) of plate or shell models, the stresses obtained from such models shall not be less than the stresses obtained from the beam-column model noted above.
Analysis Techniques – What is acceptable? Section 3.4

(c) Guyed Masts

1. An elastic three-dimensional beam-column where the mast is modeled as equivalent three-dimensional beam-column members supported by cables represented either as non-linear elastic supports or cable elements. This analysis produces moments, shear and axial forces in the mast, which results in individual member forces.

2. An elastic three-dimensional truss model where individual members of the mast are modeled as straight members connected at joints producing only axial forces in the members. The cables are represented as cable elements.

3. An elastic three-dimensional frame-truss model where continuous members (legs) of the mast are modeled as 3-D beam elements producing both moments and axial forces in the members while other members may be modeled as 3-D truss members. The cables are represented as cable elements.

Analysis Techniques – What is acceptable? Section 3.4

Loads must be equally distributed to each leg joint of the cross section at the panel points for three dimensional truss or frame models.
Analysis Techniques – What is acceptable? Section 3.4

The horizontal design wind force for appurtenances shall be distributed to each leg joint according to the location of the appurtenance.

Analysis Techniques – What is acceptable? Section 3.4

Local bending shall be considered for structural components supporting appurtenances that are supported in the middle half of a component.
Analysis Techniques – What is acceptable? Section 3.4

For main bracing members, local bending shall be considered for the condition of wind normal to the plane of the bracing members with no axial load considered.

Design Strength

• Follows AISC LRFD Criteria
• Adjusted where appropriate – Ex. Guy Wires Link plates
• Longitudinal Welds for Tubular Pole Structures
• Research data that improves or supersedes AISC criteria –
  – Welded Sections Bracing “K-factors”
  – Redundant capacity
  – Angle Bracing Capacity – Tension Restraint.
Manufacturing – General Purpose

• Primary focus – Create some minimum qualitative requirements

  – Qualified vs. Pre-qualified Steel
    • Pre-qualified – List provided – Table 5-1
    • Qualified – must meet the minimums

  – Must obtain test reports from the steel fabricator or a testing laboratory

  – Misc.
    • Guy anchors and direct embedded steel exposed to soil must be protected from low resistivity soil (50 ohm-m) or measured pH values that are below 3 or greater than 9.
    • Acceptable Corrosion Protection techniques are listed in Annex H

Pre- Qualified Steel

Steel – Is it Pre-Qualified? If not what then?

  – Carbon Equivalent cannot exceed 0.65
  – Minimum elongation of 18%
  – Charpy V-notch requirements – Thickness greater than 5”
  – Well documented
Other Structural Materials – Why this section?

• The advent of unconventional materials requires the standard to ensure this does not become a hole.
• Example: Fiberglass/Poly-fiber reinforcement

Guy Assemblies – Some Changes

Modulus of Elasticity
In the absence of specific cable manufacturer’s data, the modulus of elasticity of a steel cable used for analysis shall be 23,000 ksi [159 MPa] except for pre-stretched cables 2-9/16 in. [65 mm] diameter and smaller, a modulus of elasticity of 24,000 ksi [166 MPa] shall be used.

Proof Loading of Assemblies
Factory installed end sockets shall be proof loaded to 55 percent of the manufacturer’s rated breaking strength of the cable and held for a minimum of three cycles with a minimum duration of five minutes for each cycle.

Articulation
Articulation at both ends of guy assemblies shall be provided for assemblies consisting of non-metallic guys with rigid end connections such as end sockets or similar devices that do not include low frequency dampers. Articulation shall provide a minimum 10° rotation in both the vertical and the horizontal directions.

Guy Dampers
For guyed masts with structure heights above 1200 ft [366 m], high frequency dampers shall be provided for cables with rigid end connections such as bridge sockets or similar devices unless otherwise determined by a site-specific analysis.

Initial Tension
The initial tension in guys, for design purposes, at an ambient temperature of 60o F [16o C] shall be within upper and lower limits of 15 and 7 percent, respectively, of the manufacturer’s rated breaking strength of the strand. Values of initial tension beyond these limits may be used provided consideration is given to the sensitivity of the structure to variations in initial tension. The design ambient temperature may be adjusted based on site-specific data.
Insulators

\[ \phi_i = 0.5 \] for non-metallic fail-safe insulators
\[ \phi_i = 0.4 \] for other non-metallic insulators

Other Requirements

- Insulator assemblies shall be proof loaded to 60 percent of the manufacturer’s rated ultimate strength.
- Insulator manufacturers shall provide the expected life of base and guy insulators.

Foundations

- Recommends a geotechnical report for Class I and II structures
- Requires a geotechnical investigation for Class III structures
- Use Factored Load Reactions
  - \( \phi_r = 0.50 \) for bearing on rock or soil for bases of guyed masts including spread footings driven piles, drilled caissons, steel grillages. (Approximate FS = 2.72)
  - \( \phi_r = 0.75 \) for bearing on rock or soil for bases of self-supporting structures including spread footings, mats, driven piles, drilled caissons, steel grillages. (Approximate FS = 1.81)
  - \( \phi_r = 0.75 \) for pull-out or uplift in rock or soil for foundations and anchorages including spread footings, deadman anchors, drilled caissons, steel grillages and battered piles. (Approximate FS = 1.81)
  - \( \phi_r = 0.50 \) for pull-out or uplift in rock or soil for foundations and anchorages which utilize one rock/soil bolt, dowel or anchoring device. (Approximate FS = 2.72)
  - \( \phi_r = 0.40 \) for pull-out or uplift in rock or soil for foundations and anchorages which utilize non-battered piles with a tapered cross-section. (Approximate FS = 3.4)
  - \( \phi_r = 0.75 \) for friction or lateral resistance of soil or rock for all types of foundations. (Approximate FS = 1.81)

  Note: assumes the aggregate factor applied to the reactions is approximately 1.36. A simplification.
- Minimum Frost depth is now required.
The tower plans shall detail the following data for the site specified used in the structural analysis:

- Basic wind speed (3 second gust, 50 year return period) without ice.
- Basic wind speed (50 year return period) with ice.
- Design ice thickness (50 year return period).
- Exposure category (B, C or D) for the site specified.
- Structure classification (I, II, or III) used to classify the structure.
- Topography category (1, 2, 3, 4, or 5).
- Earthquake spectral response acceleration at short periods.
- Foundation reactions for the loading combinations considered.
- Soil design parameters or source of data.
Plans, Assembly Tolerances and Marking

- The erectors responsibility is clearer
- Drawings must show the details and markings required to allow the proper installation of the structure.
- Must include:
  - Member sizes
  - Member yield strength
  - Grade of structure bolts
  - Foundation reactions – based upon factored loads
  - Loading:
    - Antennas: Height, quantity, model, number and size of lines
    - Mounts: Height, quantity, model, number and size of lines
    - Or, the total effective projected area representative of all of the antennas and mounts at each elevation

Plans, Assembly Tolerances and Marking

Tolerances – Well defined in the standard. I do not consider them conservative if your goal is to guarantee a user friendly assembly of the structure. Actual tolerances will be a product of the manufacturers philosophy and quality philosophy.

Markings – members must be permanently labeled (character height ½")
Maintenance and Condition Assessment

Maintenance and condition assessment shall be performed as follows:

- Three-year intervals for guyed masts and five-year intervals for self-supporting structures.
- After severe wind and/or ice storms or other extreme conditions.
- Shorter inspection intervals may be required for Class III structures and structures in coastal regions, in corrosive environments, and in areas subject to frequent vandalism.

Existing Structures - Defined

As a minimum, existing structures shall be analyzed in accordance with this Standard, regardless of the standard used for the design of the original structure, under any of the following conditions:

- a change in type, size, or number of appurtenances such as antennas, transmission lines, platforms, ladders, etc.
- a structural modification, excepting maintenance, is made to the structure
- a change in serviceability requirements
- a change in the classification of the structure to a higher class in accordance with Table 2-1.

Note: Existing structures need not be re-analyzed for each revision of this Standard unless there are changed conditions as outlined above.
Existing Structures – Versions C to F

- The engineer performing an analysis of an existing structure can perform an analysis in accordance with previous revisions of the standard for informational purposes only.
- Previous versions of the standard are considered to be legally obsolete. (What is considered the Standards of the Practice of the Engineering Profession?)
- Must perform modifications in accordance with the latest revision of the standard.

Existing Structures – Types of Analysis

- **Feasibility Structural Analysis**
  - Defines impact of proposed changes
  - Macro view of the structure
  - Does not include connections
  - May assume the structure is properly constructed and maintained.

- **Rigorous Structural Analysis**
  - May assume the structure is properly constructed and maintained.
  - Use to determine the final acceptance of proposed changes.
  - Must determine the overall stability and adequacy of the structural members, foundations and connection details.
  - Foundation analysis must be site specific
  - Assumptions about details that are not visible or cannot be discerned without extensive field testing is acceptable.
Existing Structures – The minimums

• The report must state the type of analysis performed.

• A feasibility report shall state that final acceptance of changed conditions shall be based upon a rigorous structural analysis.

• Exemptions from the requirements of the main body:
  – Minimum mast shear and torsion
  – Minimum bracing resistance
  – Climbing facilities
  – Etc. See section 15.6

Existing Structures - Modifications

• Must be based upon a Rigorous Structural Analysis

• Design Document shall be prepared indicating modifications

• Prior to implementation of the modifications the data designated by the engineer shall be verified
Annex A – Procurement and User Guidelines

• Formerly called Customer Checklist
• Intended to guide purchaser
• Points the Purchaser to issues of concern
• Sets “default” values.

Annex B - County listings

• Lists the maximum and minimum values for
  – Wind, V
  – Wind on Ice, $V_i$
  – Ice, $t_i$
  – Short period $S_s$

• Pay attention to the notes, they will highlight special wind regions.
• Use the maximum if you do not have a site location within a county.
Annex C – Microwave Antennas

• Remain unchanged.
• Values are tailored to the 3-second gust

Annex D – Twist and Sway

• Remain conceptually unchanged
• Added equations, eliminated graphs

Annex E – What is a Guy Rupture? When does it apply?

It is a technique used to ensure tensile capacity in the leg connections. It applies when the leg splices do not have a minimum design strength equal to the lower of 33% of the design compression force at the splice or 500 kips. Must include eccentricities. If you meet the leg splice criteria, the guy rupture criteria is an option. Very controversial
Annex E – Guy Rupture

An accurate analysis of a guyed mast for the dynamic effects caused by the sudden rupture of a guy is very complicated as it depends on the characteristics of the rupture, the damping of the structure, the vibration of the guys and the mast, etc.

As a result an equivalent, simplified static approach is employed to simulate the behavior of the structure immediately after a guy rupture.


- Normal Soil is abolished.
- Broken into two soil types:
  - Sand
  - Clay

Table F-1: Presumptive Soil Parameters:

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>N (blows/ft)</th>
<th>θ (deg)</th>
<th>γ (lb/ft²)</th>
<th>c (psf)</th>
<th>Ultimate Bearing (psf)</th>
<th>k (pci)</th>
<th>fₜ₀</th>
</tr>
</thead>
</table>
Annex G – Geotechnical Investigations

- Lists the minimum data that should be included in a “soil report”.
- Includes Soil pH and resistivity (Corrosion Control).
- A listing that can be given to the Geotechnical Engineer

Issues postponed to revision H and Beyond.

- Fatigue
- Monopole Base Plate Design
- Stress Concentrations
- New Technology
- Aluminum
- ASD
- Corrections and adjustments